Parabolic Trough Concentrator R&D

CSP Peer Review

November 7, 2001

Receiver R&D (Heat Collector Element; HCE)

- **FLP Energy, Harper Lake SEGS 8 & 9**
- **Energy Laboratories, Inc.**
- **KJC - SEGS 3-7**
- **Sunray Energy - SEGS 1 & 2**
- **Duke Solar**
- **Industrial Solar Technology (IST)**

Concentrator R&D

- **Duke Solar**
- **Industrial Solar Technology (IST)**

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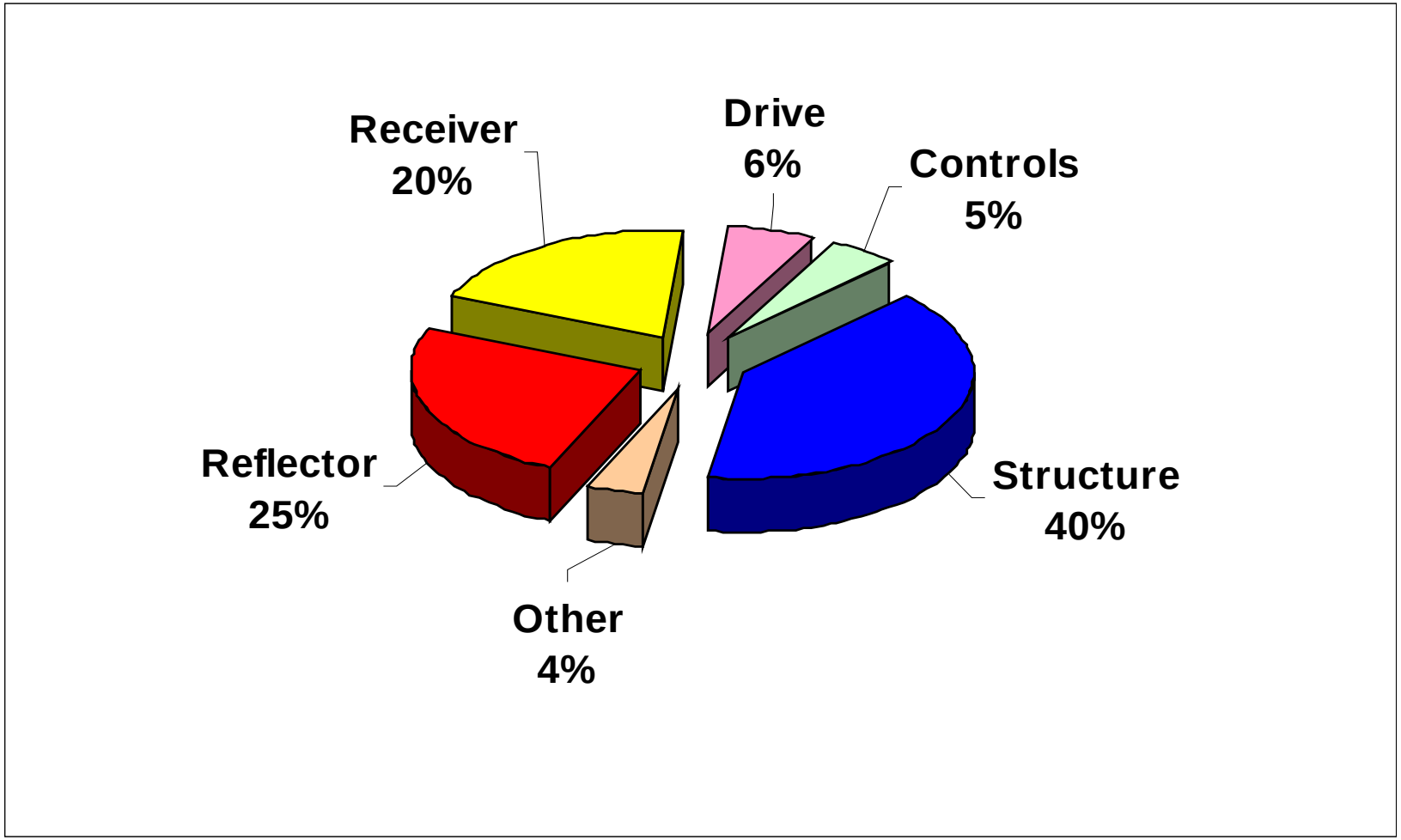
University of New Mexico – Advanced Materials Laboratory

Parabolic Concentrator Cost Breakout

From Trough Roadmap



HCE (Receiver) Reliability

Background

HCE (Receiver) failure / degradation is the single largest cost factor [both performance and O&M] for current & future plants

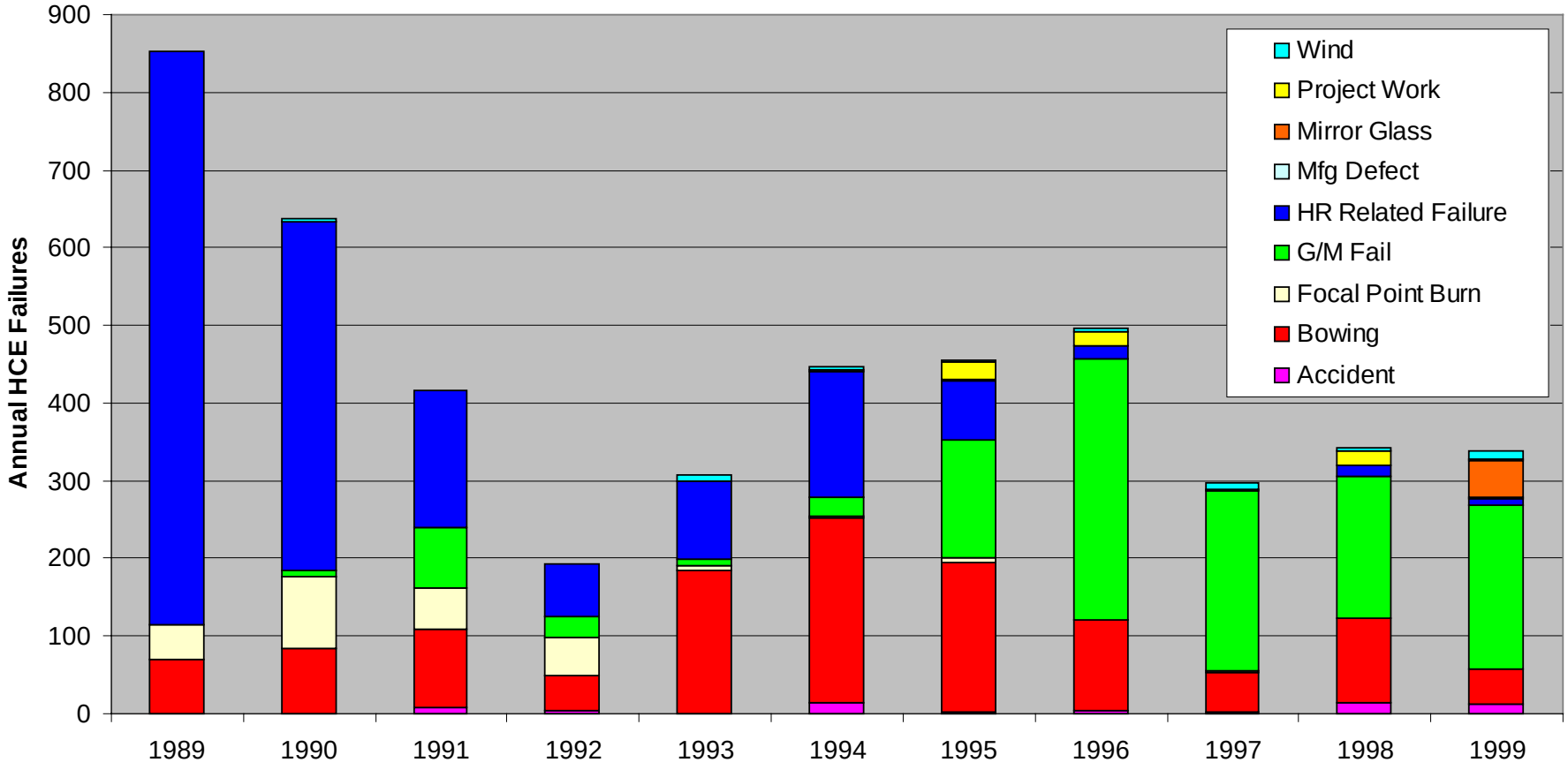
- **30-40% failure at SEGS 6 - 9 (9 to 11 years of operation)**
- **loss of vacuum (glass-to-metal seal or other), solar selective coating degradation in air, broken glass**
- **Replacement cost is ~$1000 / HCE (evacuated)**
- **Annual O&M cost is 0.5 ¢/kWh (Cost/Perf)**

Trough Receiver Development

Activities In Progress (prior to FY01)

- MWE USA Trough Phase I Contract
  - Failure Database Development (NREL)
- KJCOC/SOLEL UVAC HCE Test
  - SEGS Testing Agreement (NREL)
- SNL Receiver Development
  - HCE Degradation Analysis
  - Black Crystal Solar Selective Absorber Coating (ELI); CRADA/License
  - Low-Cost Absorber Protective Overcoat (ELI)
  - Refurbished HCE development/manufacturing support

SEGS VI LS-2 Failures by Cause



Trough Receiver Development
Full Length Split-Glass Manuf Development

3000 S-G manuf and installed - SEGS 2 in FY00

FY01 Activity
2.1.1 Trough Receiver Development

Objective: Develop a low-cost US Manufacturer of receiver

Approach:

- Conduct an industry/lab HCE design review
- Develop a low-cost non-evacuated receiver
- Prototype Advanced Low-Cost High Performance HCE
- Field testing of all concepts

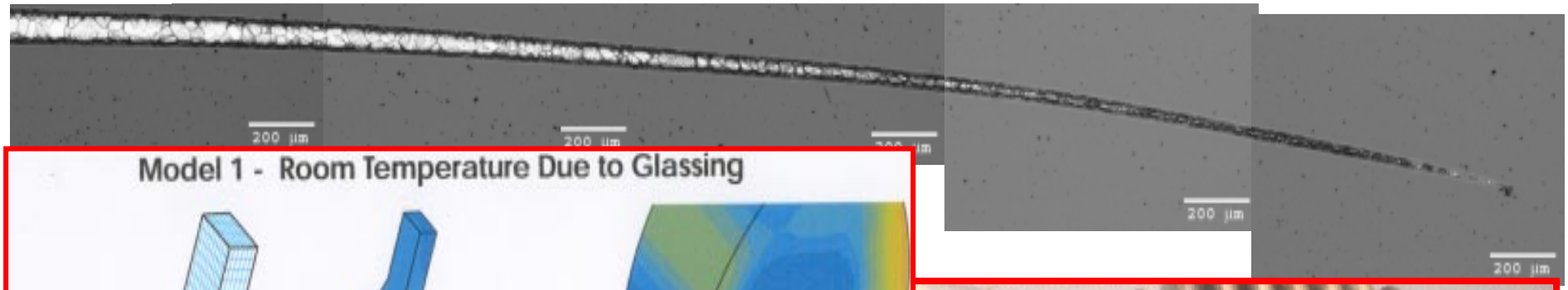
Milestones:

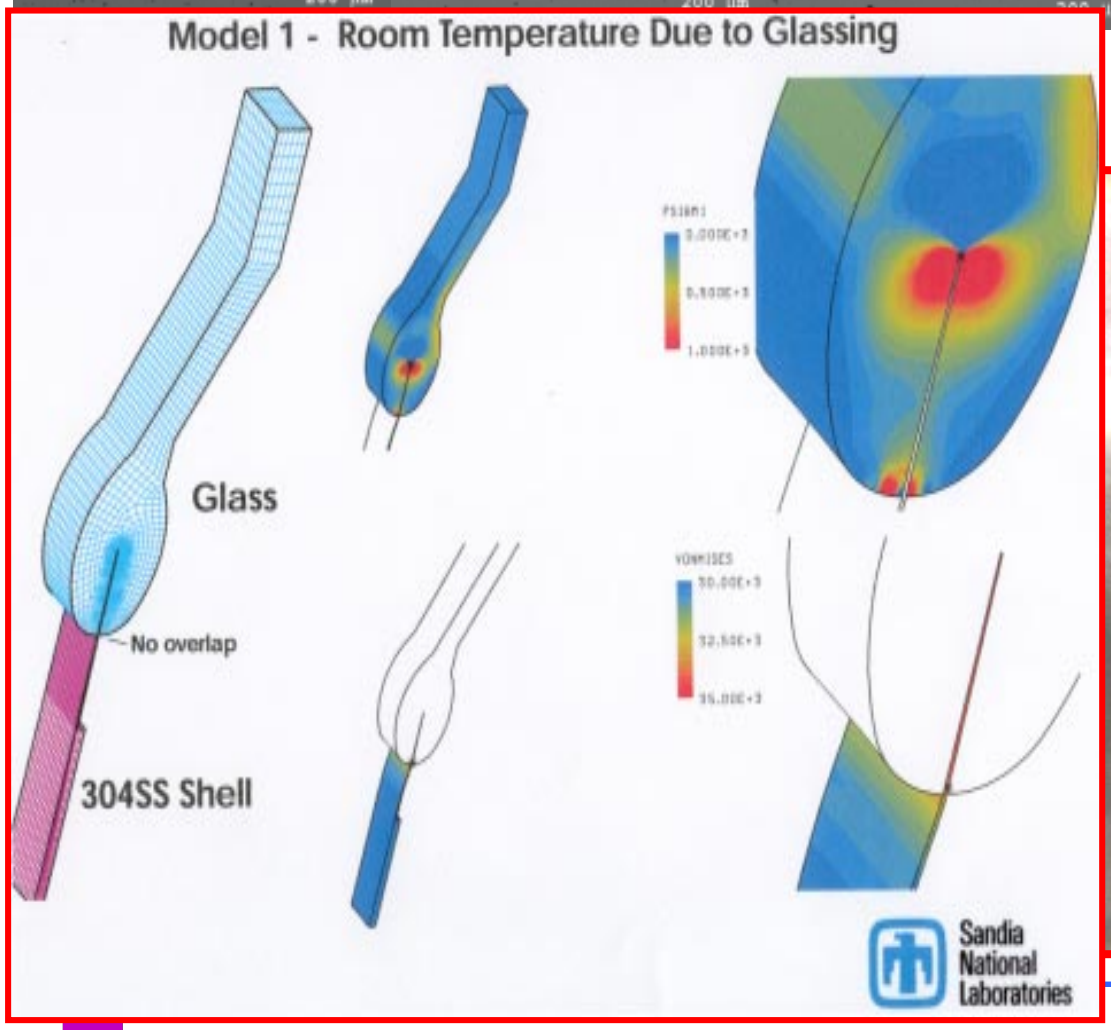
- **Receiver design review workshop (Mahoney - May 2001)**
- HCE Failure Analysis of SEGS VI & VII (Price – March 2001)
- Test of refurbished Cermet HCEs (Mahoney - March 2001)
- Test of Black Crystal HCEs (Mahoney - June 2001)
- **Test high performance HCE (Mahoney - September 2001)**
- Solel UVAC 6-Month Test Report (Price – June 2001)

	Contract	Sandia	NREL
Receiver Development	271	479	0

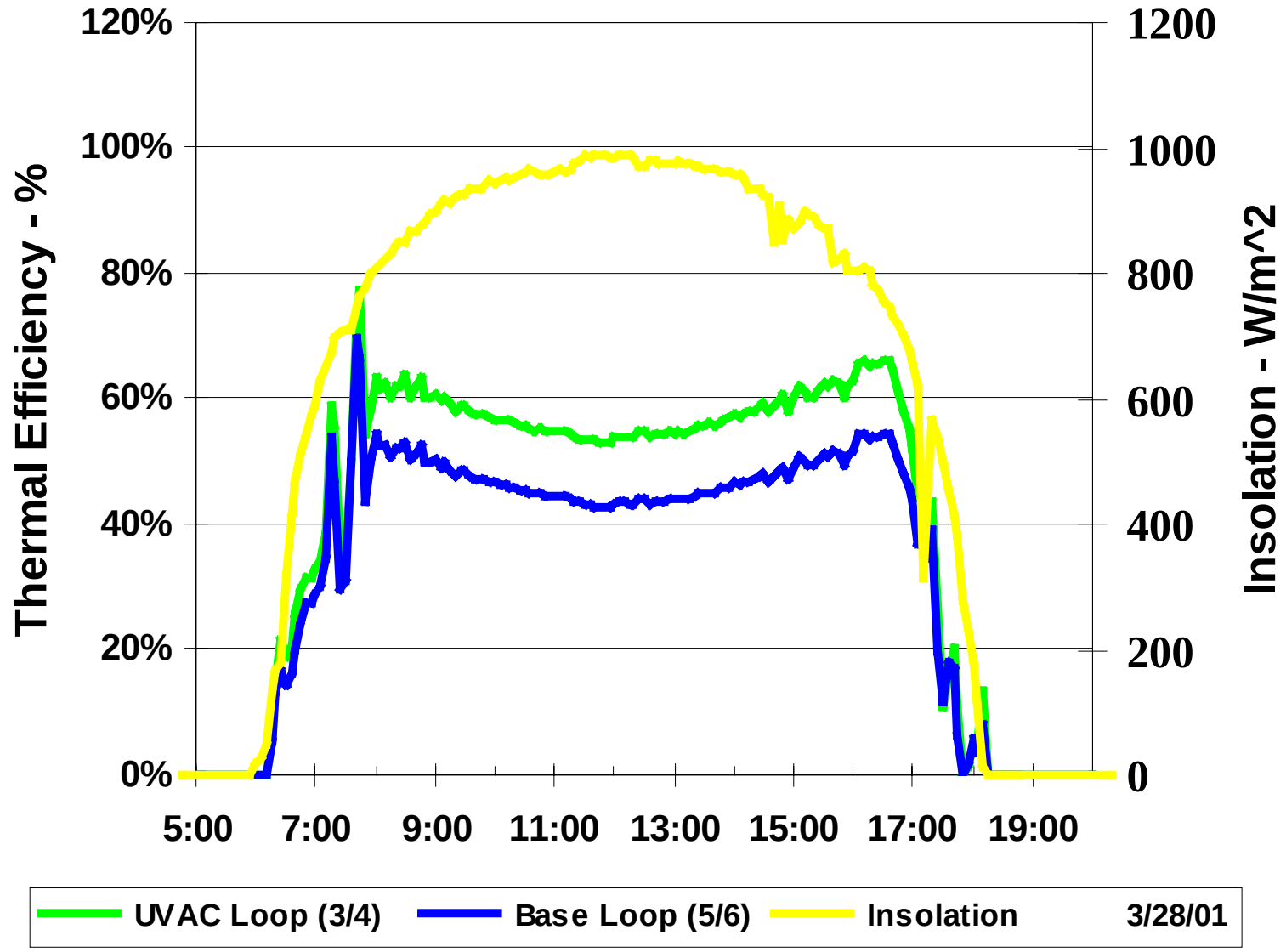
Trough Receiver Development

Fundamental Understanding of HCE Glass-to-Metal Seal Failures



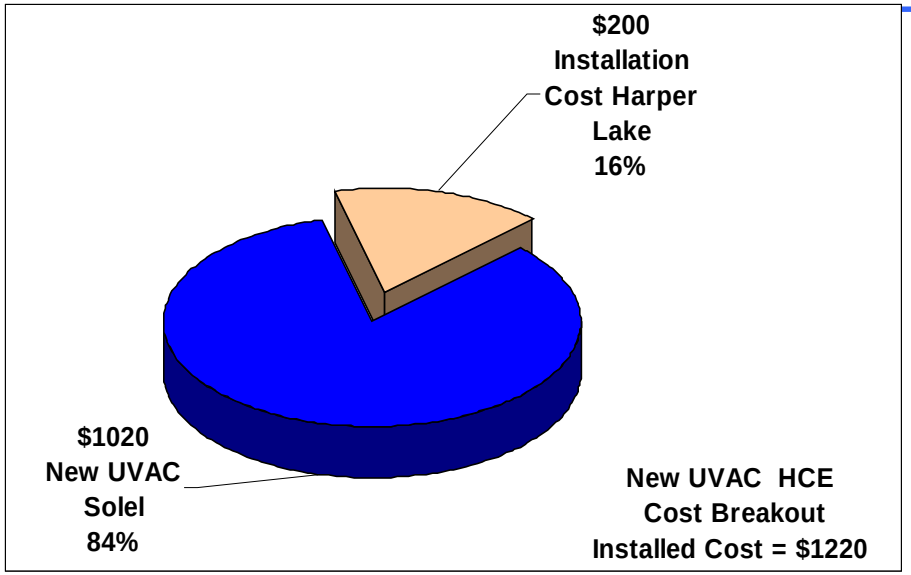


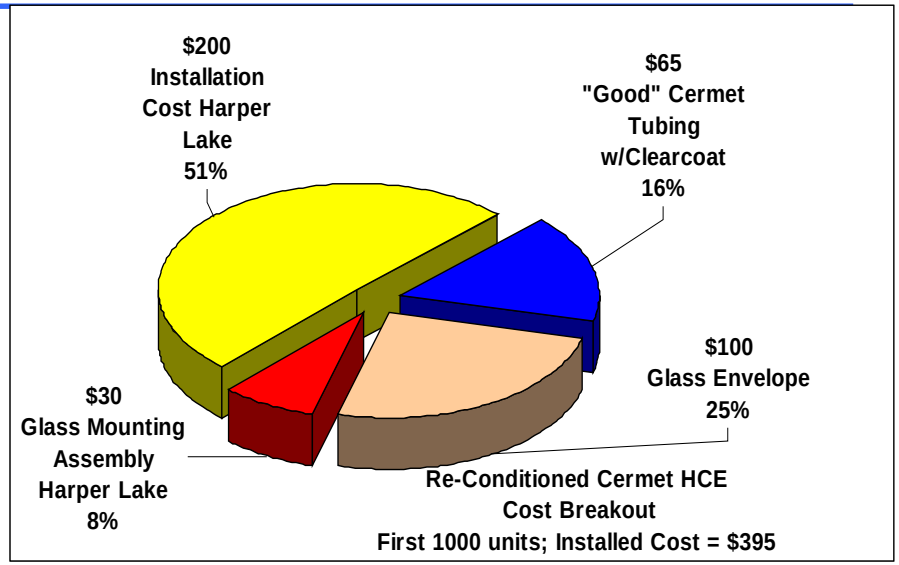
UVAC / Cermet Comparision - SEGS VI

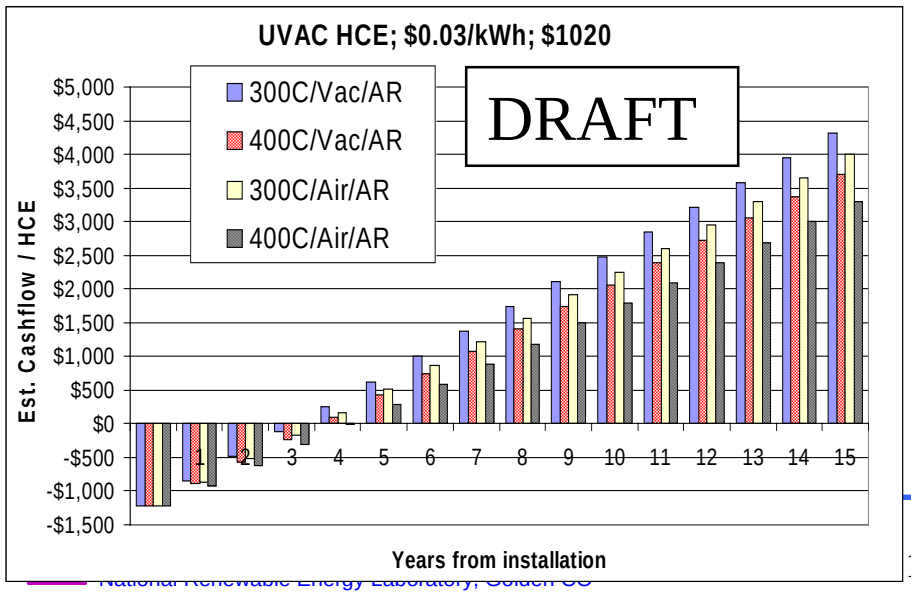


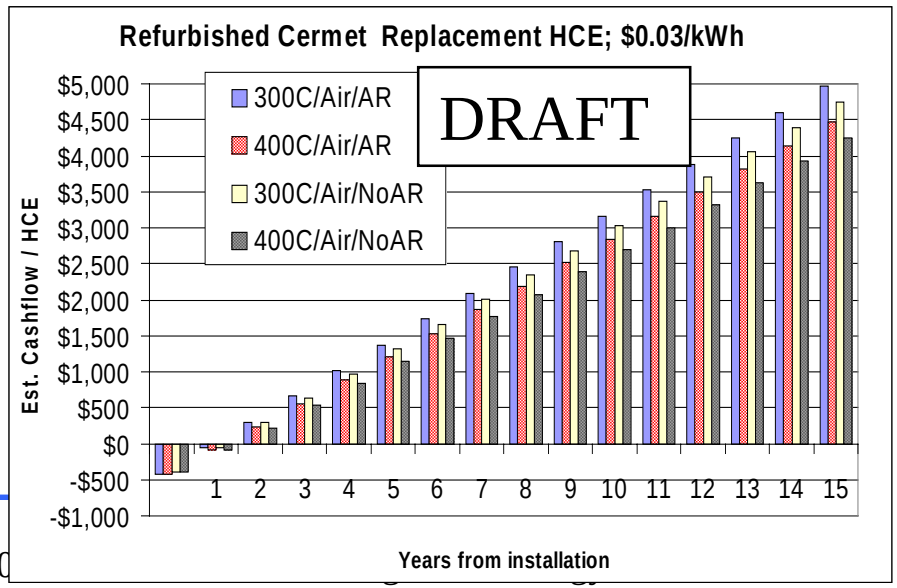
Trough Receiver Development

Cost – Performance (HCE Model) Benefits









Low-Cost Manufacturing Developments for Metal and Glass Tubing; SNL/Energy Laboratories, Inc. CRADA

550 Reconditioned receivers to FPL Harper Lake; FY01

450 more recvrs in process; FY02

Concentrating Solar Power

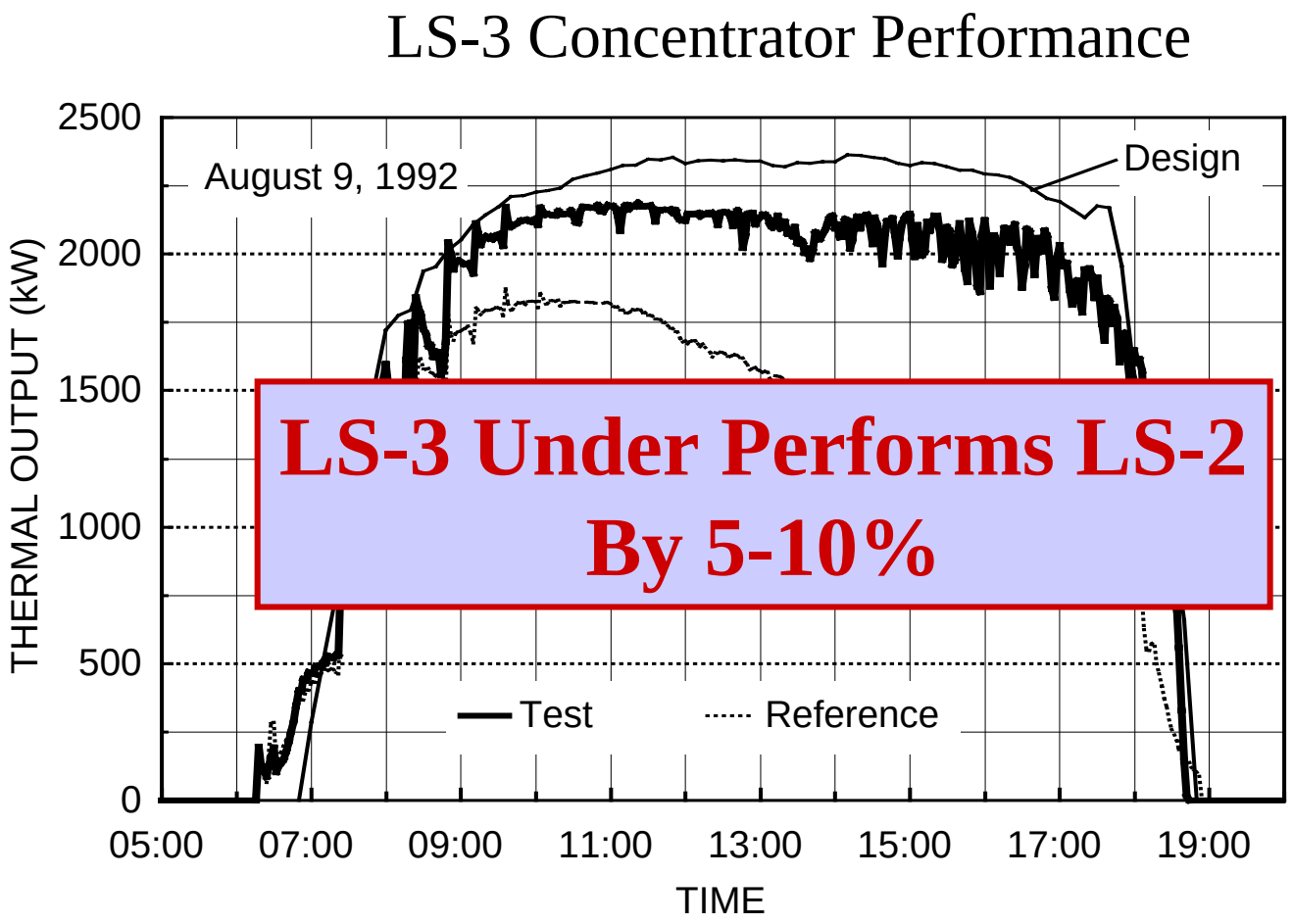
Sun♦Lab

Sandia National Laboratories, Albuquerque, NM
National Renewable Energy Laboratory, Golden CO

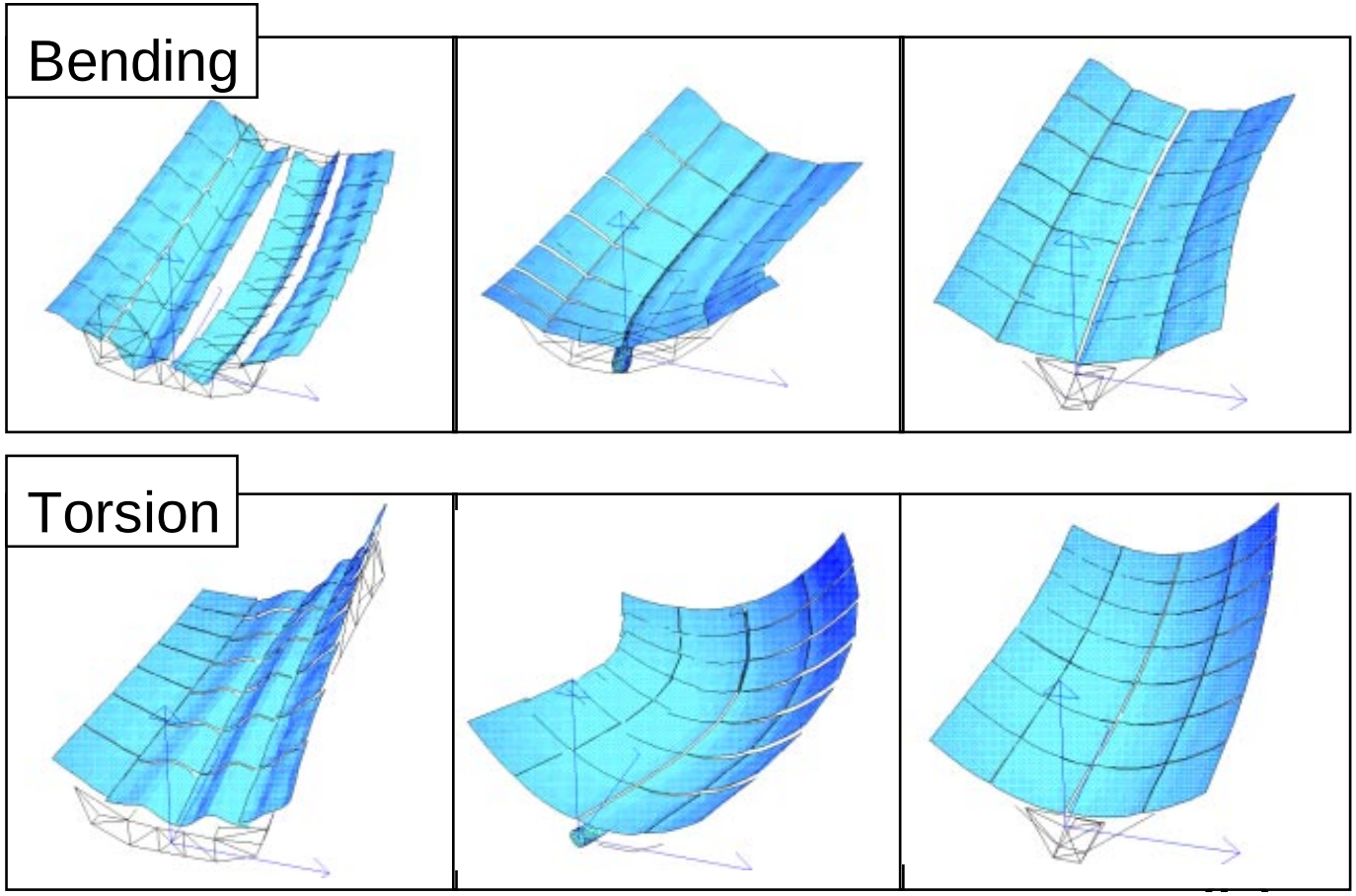
Trough Receiver Development
Priorities Moving Forward

- Priorities NREL Support
  - Failure Database Development (NREL)
  - Solel UVAC - SEGS Testing Agreement (NREL)
- SNL Receiver Development / Manufacturing
  - Encourage Progress
    - New Designs and Low-Cost Manufacturing Processes
      - Ready in FY02
    - Coating(s) development (Barrier, AR, others)
    - IST coating support
- NREL Business Development Funds
  - CEC Opportunities

Concentrator Development



Concentrator Wind Loads and Deformations



Concentrator Development

Activities In Progress (prior to FY01)

- Duke Solar USA Trough Phase I Contract
  - New GeoHub Structure
  - Secondary Receiver
  - Alternative Mirror Shape
  - Non-moving Receiver Design
- Duke Solar USA Trough Phase II Contract
  - Optimized structure and secondary receiver designs
  - ORC Optimization
  - Wind Tunnel Testing
- IST (Industrial Solar Technologies) USA Trough Phase II Contract
  - Thin glass reflector
  - Steel Structure

Original FY01 Activity
2.1.2 Near-Term Trough Concentrator

Objective: Develop a low-risk trough concentrator design

Approach:

- Create industry/lab design team and conduct DFMA type review using LS-2 and IST collectors as competing baselines
- Develop detailed design
- Develop prototype components for testing

Benefits:

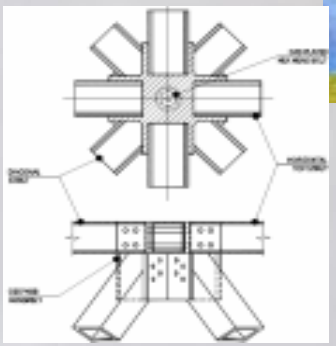
- Leverages work on existing USA Trough contracts
- Supports development of US trough industry
- Provides U.S. supplier of near-term collector design

MOS: A U.S. supplier of a trough collector for near-term projects

Partners: Duke Solar, IST, ELI, Reflective Energies, Nexant, SEGS

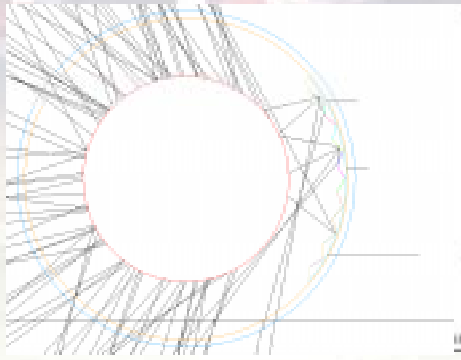
Duke Solar
Concentrator Development

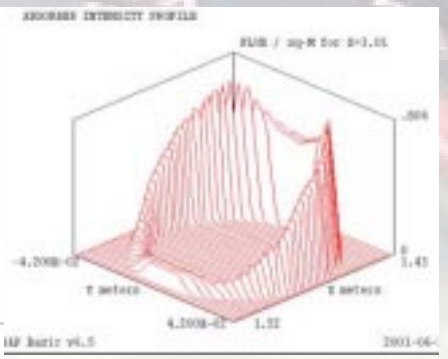
- **Objective:**
  - Develop next generation concentrator with a reduction in installed cost.
- **Activities:**
  - Wind tunnel testing
  - Optimized structure design
  - Secondary receiver optimization
- **Next Steps:**
  - Prototype tests
  - Full concentrator design
  - Field tests



Starnet GeoHubs

Est. Installed Cost
- LS-3 $47.26/m2
- Duke $49.44/m2

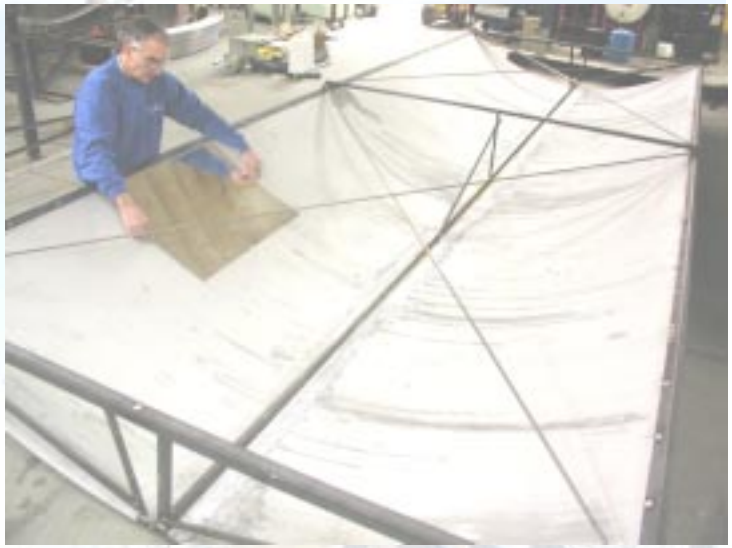


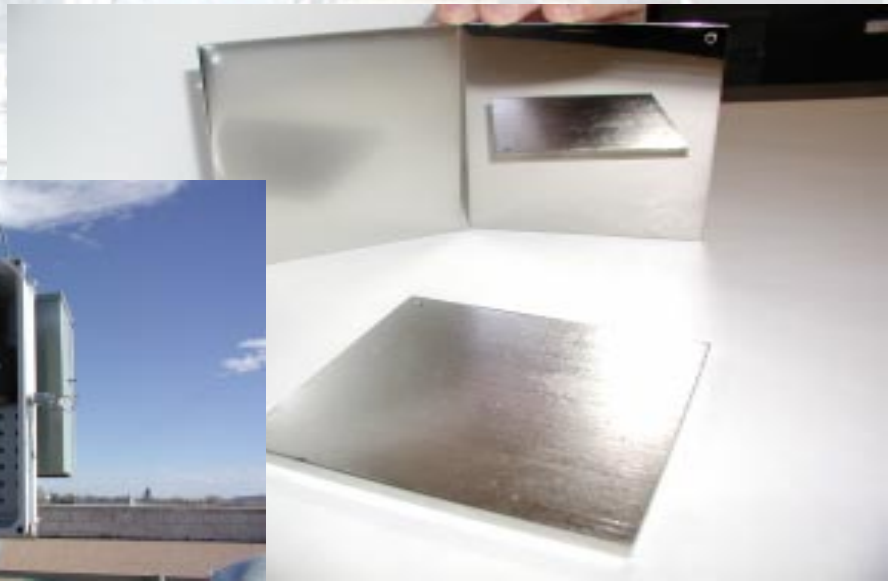


Duke Solar

Industrial Solar Technology
Concentrator Development

- **Objective:**
  - Develop lower cost and higher temperature concentrator
- **Activities:**
  - Steel concentrator structure
  - Thin glass reflector
  - Higher temperature receiver
  - Improved control system
- **Next Steps:**
  - Prototype tests
  - Field tests





Concentrator Development

Low-Cost Replacement Reflector Elements

- **> 1M reflector elements (facets) at SEGS**
  - **KJC : 2500 facets broken annually**
  - **FPL : similar**
  - **Sunray : ~8% of mirrors broken**
- **Sagged Silvered Glass Mirrors**
  - **Pilkington ONLY vendor**
  - **~$8-10 / sq. ft. (large orders [1000s] required)**
  - **US manuf capability exists – cost prohibitive at low volumes**
- **Commercially available polymeric substrates promising… mass produced**
  - **Thermally formable, structurally strong, ~$3 / sq. ft.**
    Total mirrored cost ~$6 / sq. ft.